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(54) **LIQUEFRACTURE HANDPIECE**

**ZERFLÜSSIGUNGSHANDSTÜCK**

**INSTRUMENT DE LIQUEFACTION**

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**US-A- 5 865 790**                      **US-A- 5 885 243**

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## Description

### Background of the Invention

**[0001]** This invention relates generally to the field of cataract surgery and more particularly to a handpiece for practicing the liquefracture technique of cataract removal.

**[0002]** The human eye in its simplest terms functions to provide vision by transmitting light through a clear outer portion called the cornea, and focusing the image by way of the lens onto the retina. The quality of the focused image depends on many factors including the size and shape of the eye, and the transparency of the cornea and lens.

**[0003]** When age or disease causes the lens to become less transparent, vision deteriorates because of the diminished light which can be transmitted to the retina. This deficiency in the lens of the eye is medically known as a cataract. An accepted treatment for this condition is surgical removal of the lens and replacement of the lens function by an artificial intraocular lens (IOL).

**[0004]** In the United States, the majority of cataractous lenses are removed by a surgical technique called phacoemulsification. During this procedure, a thin phacoemulsification cutting tip is inserted into the diseased lens and vibrated ultrasonically. The vibrating cutting tip liquifies or emulsifies the lens so that the lens may be aspirated out of the eye. The diseased lens, once removed, is replaced by an artificial lens.

**[0005]** A typical ultrasonic surgical device suitable for ophthalmic procedures consists of an ultrasonically driven handpiece, an attached cutting tip, and irrigating sleeve and an electronic control console. The handpiece assembly is attached to the control console by an electric cable and flexible tubes. Through the electric cable, the console varies the power level transmitted by the handpiece to the attached cutting tip and the flexible tubes supply irrigation fluid to and draw aspiration fluid from the eye through the handpiece assembly.

**[0006]** The operative part of the handpiece is a centrally located, hollow resonating bar or horn directly attached to a set of piezoelectric crystals. The crystals supply the required ultrasonic vibration needed to drive both the horn and the attached cutting tip during phacoemulsification and are controlled by the console. The crystal/horn assembly is suspended within the hollow body or shell of the handpiece by flexible mountings. The handpiece body terminates in a reduced diameter portion or nosecone at the body's distal end. The nosecone is externally threaded to accept the irrigation sleeve. Likewise, the horn bore is internally threaded at its distal end to receive the external threads of the cutting tip. The irrigation sleeve also has an internally threaded bore that is screwed onto the external threads of the nosecone. The cutting tip is adjusted so that the tip projects only a predetermined amount past the open end of the irrigating sleeve. Ultrasonic handpieces and cutting tips

are more fully described in U.S. Pat. Nos. 3,589,363; 4,223,676; 4,246,902; 4,493,694; 4,515,583; 4,589,415; 4,609,368; 4,869,715; 4,922,902; 4,989,583; 5,154,694 and 5,359,996.

**[0007]** In use, the ends of the cutting tip and irrigating sleeve are inserted into a small incision of predetermined width in the cornea, sclera, or other location. The cutting tip is ultrasonically vibrated along its longitudinal axis within the irrigating sleeve by the crystal-driven ultrasonic horn, thereby emulsifying the selected tissue in situ. The hollow bore of the cutting tip communicates with the bore in the horn that in turn communicates with the aspiration line from the handpiece to the console. A reduced pressure or vacuum source in the console draws or aspirates the emulsified tissue from the eye through the open end of the cutting tip, the cutting tip and horn bores and the aspiration line and into a collection device. The aspiration of emulsified tissue is aided by a saline flushing solution or irrigant that is injected into the surgical site through the small annular gap between the inside surface of the irrigating sleeve and the cutting tip.

**[0008]** Recently, a new cataract removal technique has been developed that involves the injection of hot (approximately 45°C to 105°C) water or saline to liquefy or gellate the hard lens nucleus, thereby making it possible to aspirate the liquefied lens from the eye. Aspiration is conducted concurrently with the injection of the heated solution and the injection of a relatively cool solution, thereby quickly cooling and removing the heated solution. This technique is more fully described in U.S. Patent No. 5,616,120 (Andrew, et al.). The apparatus disclosed in the publication, however, heats the solution separately from the surgical handpiece. Temperature control of the heated solution can be difficult because the fluid tubes feeding the handpiece typically are up to two meters long, and the heated solution can cool considerably as it travels down the length of the tube.

**[0009]** U.S. Patent No. 5,885,243 (Capetan, et al.) discloses a handpiece having a separate pumping mechanism and resistive heating element. Such a structure adds unnecessary complexity to the handpiece.

**[0010]** Therefore, a need continues to exist for a simple surgical handpiece and tip that can heat internally the solution used to perform the liquefracture technique.

**[0011]** GB-A-1445488 discloses a surgical handpiece with a fine pulsating high velocity liquid jet having a pulse frequency of between 0.25 and 333 pulses per second, a pressure above atmospheric of between 15 to about 3500 p.s.i. (103 to about 24132 kN/m<sup>2</sup>) and having a velocity of between 50 and 500 ft. per second (15.24 and 152.40 m./sec.). A nozzle tip comprising a pair of coaxial inner and outer tubes defining an annular injection conduit is described, terminating in a closed distal end defining fine injection ports, which may be directed inwardly to converge on the jet-subjected tissue that is sucked into the inner tube.

### Brief Summary of the Invention

**[0012]** The present invention improves upon the prior art by providing a surgical handpiece, in accordance with claims which follow having two coaxially mounted tubes or channels mounted to a body. The first tube is used for aspiration and is smaller in diameter than the second tube so as to create an annular passage between the first and second tube. The annular gap communicates with a pumping chamber formed between two electrodes. The pumping chamber works by boiling a small volume of the surgical fluid. As the fluid boils, it expands rapidly, thereby propelling the liquid downstream of the pumping chamber out of the annular gap. The distal end of the annular gap is sealed by sealing together the distal ends of the first and second tube and a plurality of orifices or ports may be formed near the seal. As the expanding gas is propelled down the annular gap, the gas/liquid stream is forced out of the distal ports in a controlled and directed manner.

**[0013]** Accordingly, one objective of the present invention is to provide a surgical handpiece having at least two coaxial tubes.

**[0014]** Another objective of the present invention is to provide a handpiece having a pumping chamber.

**[0015]** Another objective of the present invention is to provide a surgical handpiece having a device for delivering the surgical fluid through the handpiece in pulses.

**[0016]** Still another objective of the present invention is to provide a handpiece having a pumping chamber formed by two electrodes.

**[0017]** Yet another objective of the present invention is to provide a handpiece having two electrodes wherein the electrodes are insulated.

**[0018]** Still another objective of the present invention is to provide a handpiece that delivers fluid pulses in a controlled and directed manner.

**[0019]** These and other advantages and objectives of the present invention will become apparent from the detailed description and claims that follow.

### Brief Description of the Drawings

#### [0020]

FIG. 1 is a front, upper left perspective view of a typical liquefracture handpiece.

FIG. 2 is a rear, upper right perspective view of the handpiece FIG. 1.

FIG. 3 is a cross-sectional view of the handpiece of FIG. 1 taken along a plane passing through the irrigation channel.

FIG. 4 is a cross-sectional view of the handpiece of FIG. 1 taken along a plane passing through the aspiration channel.

FIG. 5 is an enlarged partial cross-sectional view of the handpiece taken at circle 5 in FIG. 4.

FIG. 6 is an enlarged partial cross-sectional view of

the handpiece taken at circle 6 in FIG. 3.

FIG. 7 is an enlarged cross-sectional view of the handpiece of FIG. 1 taken at circle 7 in FIGS. 3 and 4.

FIG. 8 is a partial cross-sectional view of a first embodiment of the handpiece of the present invention.

FIG. 9 is an enlarged partial cross-sectional view of the first embodiment of the handpiece of the present invention taken at circle 9 in FIG. 8.

FIG. 10 is an enlarged partial cross-sectional view of the pumping chamber used in the first embodiment of the handpiece of the present invention taken at circle 10 in FIG. 9.

FIG. 11 is a partial cross-sectional view of a second embodiment of the handpiece of the present invention.

FIG. 12 is an enlarged partial cross-sectional view of the distal end of the second embodiment of the handpiece of the present invention taken at circle 12 in FIG. 11.

FIG. 13 is an enlarged partial cross-sectional view of the pumping chamber used in the second embodiment of the handpiece of the present invention shown in FIGS. 11 and 12.

FIG. 14 is a front perspective view of one embodiment of a distal tip that may be used with the handpiece of the present invention.

FIG. 15 is a front perspective view of a second embodiment of a distal tip that may be used with the handpiece of the present invention.

FIG. 16 is a front perspective view of a third embodiment of a distal tip that may be used with the handpiece of the present invention.

FIG. 17 is a front perspective view of an alternative a distal tip.

FIG. 18 is a front perspective view of a fourth embodiment of a distal tip that may be used with the handpiece of the present invention.

FIG. 19 is a longitudinal cross-sectional view of the tip illustrated in FIG. 18.

FIG. 20A is a front perspective view of a fifth embodiment of a distal tip that may be used with the handpiece of the present invention operating at high pressure with a short coherence length.

FIG. 20B is a front perspective view of a fifth embodiment of a distal tip that may be used with the handpiece of the present invention operating at low pressure with a long coherence length.

FIG. 21 is a block diagram of a control system that can be used with the handpiece of the present invention.

### Detailed Description of the Invention

**[0021]** Handpiece 10, not forming part of the present invention, generally includes handpiece body 12 and operative tip 16. Body 12 generally includes external irrigation tube 18 and aspiration fitting 20. Body 12 is sim-

ilar in construction to well-known in the art phacoemulsification handpieces and may be made from plastic, titanium or stainless steel. As best seen in FIG. 6, operative tip 16 includes tip/cap sleeve 26, needle 28 and tube 30. Sleeve 26 may be any suitable commercially available phacoemulsification tip/cap sleeve or sleeve 26 may be incorporated into other tubes as a multi-lumen tube. Needle 28 may be any commercially available hollow phacoemulsification cutting tip, such as the TURBOSONICS tip available from Alcon Laboratories, Inc., Fort Worth, Texas. Tube 30 may be any suitably sized tube to fit within needle 28, for example 29 gauge hypodermic needle tubing.

**[0022]** As best seen in FIG. 5, tube 30 is free on the distal end and connected to boiling or pumping chamber 42 on the proximal end. Tube 30 and pumping chamber 42 may be sealed fluid tight by any suitable means having a relatively high melting point, such as a silicone gasket, glass frit or silver solder. Fitting 44 holds tube 30 within bore 48 of aspiration horn 46. Bore 48 communicates with fitting 20, which is journaled into horn 46 and sealed with O-ring seal 50 to form an aspiration pathway through horn 46 and out fitting 20. Horn 46 is held within body 12 by O-ring seal 56 to form irrigation tube 52 which communicates with irrigation tube 18 at port 54.

**[0023]** As best seen in FIG. 7, pumping chamber 42 contains a relatively large pumping reservoir 43 that is sealed on both ends by electrodes 45 and 47. Electrical power is supplied to electrodes 45 and 47 by insulated wires, not shown. In use, surgical fluid (e.g. saline irrigating solution) enters reservoir 43 through tube 34 and check valve 53, check valves 53 being well-known in the art. Electrical current (preferably Radio Frequency Alternating Current or RFAC) is delivered to and across electrodes 45 and 47 because of the conductive nature of the surgical fluid. As the current flows through the surgical fluid, the surgical fluid boils. As the surgical fluid boils, it expands rapidly out of pumping chamber 42 through tube 30 (check valve 53 prevents the expanding fluid from entering tube 34). The expanding gas bubble pushes the surgical fluid in tube 30 downstream of pumping chamber 42 forward. Subsequent pulses of electrical current form sequential gas bubbles that move surgical fluid down tube 30. The size and pressure of the fluid pulse obtained by pumping chamber 42 can be varied by varying the length, timing and/or power of the electrical pulse sent to electrodes 45 and 47 and by varying the dimensions of reservoir 43. In addition, the surgical fluid may be preheated prior to entering pumping chamber 42. Preheating the surgical fluid will decrease the power required by pumping chamber 42 and/or increase the speed at which pressure pulses can be generated.

**[0024]** As best seen in FIGS. 8-10, in a first embodiment of the present invention, handpiece 110 generally includes body 112, having power supply cable 113, irrigation/aspiration lines 115, pumping chamber supply line 117. Distal end 111 of handpiece 110 contains

pumping chamber 142 having a reservoir 143 formed between electrodes 145 and 147. Electrodes 145 and 147 are preferably made from aluminum, titanium, carbon or other similarly conductive materials and are electrically insulated from each other and body 112 by insulating layer 159 such as anodized layer 159 formed on electrodes 145 and 147. Anodized layer 159 is less conductive than untreated aluminum and thus, acts as an electrical insulator. Electrodes 145 and 147 and electrical terminals 161 and 163 are not anodized and thus, are electrically conductive. Layer 159 may be formed by any suitable insulating or anodization technique, well-known in the art, and electrodes 145 and 147 and electrical terminals 161 and 163 may be masked during anodization or machined after anodization to expose bare aluminum. Electrical power is supplied to electrodes 145 and 147 through terminals 161 and 163 and wires 149 and 151, respectively. Fluid is supplied to reservoir 143 through supply line 117 and check valve 153. Extending distally from pumping chamber 142 is outer tube 165 that coaxially surrounds aspiration or inner tube 167. Tubes 165 and 167 may be of similar construction as tube 30. Tube 167 is of slightly smaller diameter than tube 165, thereby forming an annular passage or gap 169 between tube 165 and tube 167. Annular gap 169 fluidly communicates with reservoir 143.

**[0025]** In use, surgical fluid enters reservoir 143 through supply line 117 and check valve 153. Electrical current is delivered to and across electrodes 145 and 147 because of the conductive nature of the surgical fluid. As the current flows through the surgical fluid, the surgical fluid boils. As the surgical fluid boils, it expands rapidly out of pumping chamber 142 through annular gap 169. The expanding gas bubble pushes forward the surgical fluid in annular gap 169 downstream of pumping chamber 142. Subsequent pulses of electrical current form sequential gas bubbles that move or propel the surgical fluid down annular gap 169.

**[0026]** One skilled in the art will recognize that the numbering in FIGS. 8-10 is identical to the numbering in FIGS. 1-7 except for the addition of "100" in FIGS. 8-10.

**[0027]** As best seen in FIGS. 11-13, in a second embodiment of the present invention, handpiece 210 generally includes body 212, having power supply cable 213, irrigation/aspiration lines 215, pumping chamber supply line 217. Distal end 211 of handpiece 210 contains pumping chamber 242 having a reservoir 243 formed between electrodes 245 and 247. Electrodes 245 and 247 are preferably made from aluminum and electrically insulated from each other and body 212 by anodized layer 259 formed on electrodes 245 and 247. Anodized layer 259 is less conductive than untreated aluminum and thus, acts as an electrical insulator. Electrodes 245 and 247 and electrical terminals 261 and 263 are not anodized and thus, are electrically conductive. Layer 259 may be formed by any suitable anodization technique, well-known in the art, and electrodes 245 and

247 and electrical terminals 261 and 263 may be masked during anodization or machined after anodization to expose bare aluminum. Electrical power is supplied to electrodes 245 and 247 through terminals 261 and 263 and wires 249 and 251, respectively. Fluid is supplied to reservoir 243 through supply line 217 and check valve 253. Extending distally from pumping chamber 242 is outer tube 265 that coaxially surrounds aspiration or inner tube 267. Tubes 265 and 267 may be of similar construction as tube 30. Tube 267 is of slightly smaller diameter than tube 265, thereby forming an annular passage or gap 269 between tube 265 and tube 267. Annular gap 269 fluidly communicates with reservoir 243.

**[0028]** In use, surgical fluid enters reservoir 243 through supply line 217 and check valve 253. Electrical current is delivered to and across electrodes 245 and 247 because of the conductive nature of the surgical fluid. As the current flows through the surgical fluid, the surgical fluid boils. The current flow progresses from the smaller electrode gap section to the larger electrode gap section, i.e., from the region of lowest electrical resistance to the region of higher electrical resistance. The boiling wavefront also progresses from the smaller to the larger end of electrode 247. As the surgical fluid boils, it expands rapidly out of pumping chamber 242 through annular gap 269. The expanding gas bubble pushes forward the surgical fluid in annular gap 269 downstream of pumping chamber 242. Subsequent pulses of electrical current form sequential gas bubbles that move or propel the surgical fluid down annular gap 269.

**[0029]** One skilled in the art will recognize that the numbering in FIGS. 11-13 is identical to the numbering in FIGS. 1-7 except for the addition of "200" in FIGS. 11-13.

**[0030]** As best seen in FIGS. 14-16 and 18-20, a variety of different distal tips may be used with the handpiece of the present invention. For example, as illustrated in FIGS. 14-16, tip 600 may contain distal end 602 having a plurality of discharge orifices 604. Orifices 604 may be arranged in a divergent pattern, as illustrated in FIG. 14, a convergent pattern, as illustrated in FIG. 15, or in a non-converging, near miss pattern, as illustrated in FIG. 16, depending upon the targeted tissue and the desired surgical outcome. The converging streams create a high pressure region where the streams meet, producing a zone of maximum liquefaction. The diverging streams exhibit maximum average pressure directly in front of tip 600, making that the most efficient liquefaction zone in that region. The near miss streams create a region of high shear between the streams, which can contribute to shear fracture of the material in the proximity of tip 600. One skilled in the art will recognize that orifices 604 may be arranged so as to create the designed pattern external to tip 600 or internal to bore 611. Distal end 602 may be formed, for example by crimping the ends of tubes 165 and 167, or 265 and 267, respec-

tively (as illustrated in FIGS. 19 and 20) so that annular gap 169 or 269 is in fluid communication with orifices 604. One skilled in the art will recognize that tip 600 may be formed as a separate piece and press fit or otherwise attached to tubes 165 and 167 or 265 and 267 so that tips 600 may be interchangeable. For example, different tip 600 designs may be desired during different portions of a surgical procedure.

**[0031]** Alternatively, as illustrated in FIG. 17, tip 600' may be closed on distal end 602' so that discharge orifices 604' project fluid to the targeted tissue, but tip 600' performs no aspiration function.

**[0032]** As seen in FIGS. 18 and 19, distal end 602" of tip 600", in addition to discharge orifices 604" projecting forward and outward discharge streams 611, may contain orifice or orifices 606 that discharge a fluid stream 610 rearward into aspiration bore 608. Stream 610 helps to assure that bore 608 does not become occluded at end 602".

**[0033]** While several embodiments of the handpiece of the present invention are disclosed, any handpiece producing adequate pressure pulse force, temperature, rise time and frequency may also be used. For example, any handpiece producing a pressure pulse force of between 0.02 grams and 20.0 grams, with a rise time of between 1 gram/second and 20,000 grams/second and a frequency of between 1 Hz and 200 Hz may be used, with between 10 Hz and 100 Hz being most preferred. The pressure pulse force and frequency will vary with the hardness of the material being removed. For example, the inventors have found that a lower frequency with a higher pulse force is most efficient at debulking and removing the relatively hard nuclear material, with a higher frequency and lower pulse force being useful in removing softer epinuclear and cortical material. Infusion pressure, aspiration flow rate and vacuum limit are similar to current phacoemulsification techniques.

**[0034]** As seen in FIGS. 20A and 20B, the inventors have determined that the coherence length of the fluid stream is affected by many factors, including the properties of the fluid, ambient conditions, orifice geometry, flow regime at the orifice and pressure of the fluid. By varying the operating parameters of the system (e.g., pressure, temperature, flow development), the coherence length of the fluid pulse stream can be varied. Tip 700 contains orifice 704 internal to bore 708. When operated at relatively high pressures, as shown in FIG. 20A, the coherence length of discharge stream 711 is relatively short, degrading internal to bore 708 around distal end 702. As seen in FIG. 20B, when operated at relatively low pressures, the coherence length of discharge stream 711 is relatively long, degrading external to bore 708, past distal end 702. For example, a pressure stream having a coherence length of approximately between -1.0 millimeters and +5.0 millimeters from distal end 702 is suitable for use in ophthalmic surgery.

**[0035]** As seen in FIG. 21, one embodiment of control system 300 for use in operating handpiece 310 includes

control module 347, power gain RF amplifier 312 and function generator 314. Power is supplied to RF amplifier 312 by DC power supply 316, which preferably is an isolated DC power supply operating at several hundred volts, but typically  $\pm 200$  volts. Control module 347 may be any suitable microprocessor, micro controller, computer or digital logic controller and may receive input from operator input device 318. Function generator 314 provides the electric wave form in kilohertz to amplifier 312 and typically operates at around 450 kHz or above to help minimize corrosion.

**[0036]** In use, control module 347 receives input from surgical console 320. Console 320 may be any commercially available surgical control console such as the LEGACY® SERIES TWENTY THOUSAND® surgical system available from Alcon Laboratories, Inc., Fort Worth, Texas. Console 320 is connected to handpiece 310 through irrigation line 322 and aspiration line 324, and the flow through lines 322 and 324 is controlled by the user via footswitch 326. Irrigation and aspiration flow rate information in handpiece 310 is provided to control module 347 by console 320 via interface 328, which may be connected to the ultrasound handpiece control port on console 320 or to any other output port. Control module 347 uses footswitch 326 information provided by console 320 and operator input from input device 318 to generate two control signals 330 and 332. Signal 332 is used to operate pinch valve 334, which controls the surgical fluid flowing from fluid source 336 to handpiece 310. Fluid from fluid source 336 is heated in the manner described herein. Signal 330 is used to control function generator 314. Based on signal 330, function generator 314 provides a wave form at the operator selected frequency and amplitude determined by the position of footswitch 326 to RF amplifier 312 which is amplified to advance the powered wave form output to handpiece 310 to create heated; pressurized pulses of surgical fluid.

**[0037]** Any of a number of methods can be employed to limit the amount of heat introduced into the eye. For example, the pulse train duty cycle of the heated solution can be varied as a function of the pulse frequency so that the total amount of heated solution introduced into the eye does not vary with the pulse frequency. Alternatively, the aspiration flow rate can be varied as a function of pulse frequency so that as pulse frequency increases aspiration flow rate increases proportionally.

**[0038]** This description is given for purposes of illustration and explanation. It will be apparent to those skilled in the relevant art that changes and modifications may be made to the invention described above without departing from the scope of the appended claims. For example, it will be recognized by those skilled in the art that the present invention may be combined with ultrasonic and/or rotating cutting tips to enhance performance.

## Claims

1. A surgical handpiece (110, 210) for lens removal using a pulsed and heated fluid stream comprising:
  - a tip (600, 600", 700) which can be inserted into the eye and
  - a body (112, 212), said tip and said body comprising an injection channel suitable to discharge a sequence of heated surgical fluid pulses, and an aspiration channel;
  - said injection channel and said aspiration channel being defined by an aspiration tube (167, 267) coaxially mounted within an outer tube (165, 265) so as to form an annular channel (169, 269) between the aspiration tube and the outer tube, said annular channel having a generally closed distal end (602, 602", 702);
  - a pumping chamber (142, 242) mounted within the body, said pumping chamber comprising a reservoir (143, 243) formed by two electrodes (145, 147; 245, 247) and in fluid communication with the annular channel (169, 269), such that current flowing between the electrodes causes surgical fluid in the pumping chamber to boil ;
  - a supply line (217) to supply surgical fluid to the reservoir, said supply line comprising a check valve (153, 253);
  - conductors and connectors to supply current to said electrodes; and
  - at least one discharge orifice (604, 604", 704) arranged in said distal end of said annular channel and adapted such that when surgical fluid is caused to be boiled in the pumping chamber, a heated surgical fluid pulse is discharged from said discharge orifice in a directed manner.
2. The handpiece (110) of claim 1, wherein said pumping chamber reservoir (143) is defined on opposite sides thereof by a pair of electrodes (145, 147) that allow electrical current to flow across the electrodes when a surgical fluid is contained within the reservoir, so as to boil said surgical fluid and propel said surgical fluid down said annular channel.
3. The handpiece of claim 2, wherein the electrodes are electrically insulated from each other and from the body by an anodized layer (159).
4. The handpiece of any of claims 1 to 3, wherein a plurality of discharge orifices (604) are arranged in said distal end, in a divergent pattern, a convergent pattern, or in a non-converging, near miss pattern.
5. The handpiece of any of claims 1 to 4, further comprising at least one discharge orifice (606) arranged in said distal end of said annular channel to dis-

charge a stream of heated surgical fluid (610) rearwardly into said aspiration channel.

gegeneinander und gegen den Körper durch eine anodisierte Schicht (159) elektrisch isoliert sind.

## Patentansprüche

1. Chirurgisches Handstück (110, 210) zur Linsenentfernung unter Verwendung eines gepulsten und erwärmten Fluidstromes, das umfaßt:

eine Spitze (600, 600", 700), die in das Auge eingeführt werden kann und einen Körper (112, 212), wobei die Spitze und der Körper einen Injektionskanal, der dazu geeignet ist, eine Folge von Pulsen eines erwärmten chirurgischen Fluids abzugeben, und einen Ansaugkanal aufweisen;

wobei der Injektionskanal und der Ansaugkanal durch ein Ansaugrohr (167, 267) definiert sind, das koaxial in einem äußeren Rohr (165, 265) montiert ist, um einen ringförmigen Kanal (169, 269) zwischen dem Ansaugrohr und dem äußeren Rohr zu bilden, wobei der ringförmige Kanal ein im allgemeinen geschlossenes distales Ende (602, 602", 702) umfaßt; eine Pumpkammer (142, 242), die im Körper montiert ist, wobei die Pumpkammer ein Reservoir (143, 243) umfaßt, das durch zwei Elektroden (145, 147; 245, 247) gebildet ist und in Fluidkommunikation mit dem ringförmigen Kanal (169, 269) steht, so daß ein Strom, der zwischen den Elektroden fließt, chirurgisches Fluid in der Pumpkammer zum Sieden bringt; eine Versorgungsleitung (217), um chirurgisches Fluid zum Reservoir zuzuführen, wobei die Versorgungsleitung ein Rückschlagventil (153, 253) umfaßt; Leitungen und Stecker, um Strom zu den Elektroden zuzuführen; und zumindest eine Austrittsöffnung (604, 604", 704), die im distalen Ende des ringförmigen Kanals angeordnet ist und dazu angepaßt ist, daß, wenn chirurgisches Fluid in der Pumpkammer zum Sieden gebracht wird, ein Puls eines erwärmten chirurgischen Fluids aus der Austrittsöffnung in einer gerichteten Weise abgegeben wird.

2. Handstück (110) nach Anspruch 1, wobei das Pumpkammerreservoir (143) auf gegenüberliegenden Seiten desselben durch ein Paar von Elektroden (145, 147) definiert ist, die ermöglichen, daß ein elektrischer Strom über die Elektroden fließt, wenn ein chirurgisches Fluid im Reservoir enthalten ist, um das chirurgische Fluid zum Sieden zu bringen und das chirurgische Fluid im ringförmigen Kanal anzutreiben.

3. Handstück nach Anspruch 2, wobei die Elektroden

4. Handstück nach einem der Ansprüche 1 bis 3, wobei eine Mehrzahl von Austrittsöffnungen (604) im distalen Ende in einem divergenten Muster, einem konvergenten Muster oder in einem nicht konvergierenden etwas verfehlenden Muster angeordnet sind.

5. Handstück nach einem der Ansprüche 1 bis 4, das des weiteren zumindest eine Austrittsöffnung (606) aufweist, die im distalen Ende des ringförmigen Kanals angeordnet ist, um einen Strom erwärmten chirurgischen Fluids (610) rückwärts in den Ansaugkanal abzugeben.

## Revendications

1. Pièce à main chirurgicale (110, 210) pour enlever un cristallin en utilisant un jet de fluide pulsé et chauffé, comportant :

une pointe (600, 600", 700) qui peut être insérée dans l'oeil, et

un corps (112, 212), ladite pointe et ledit corps comportant un canal d'injection adapté pour décharger une série d'impulsions de fluide chirurgical chauffé, et un canal d'aspiration, ledit canal d'injection et ledit canal d'aspiration étant définis par un tube d'aspiration (167, 267) monté coaxialement dans un tube extérieur (165, 265) de manière à former un canal annulaire (169, 269) entre le tube d'aspiration et le tube extérieur, ledit canal annulaire ayant une extrémité distale généralement fermée (602, 602", 702),

une chambre de pompage (142, 242) montée dans le corps, ladite chambre de pompage comportant un réservoir (143, 243) formé par deux électrodes (145, 147 ; 245, 247) et en communication de fluide avec le canal annulaire (169, 269), de sorte qu'un courant circulant entre les électrodes porte à ébullition le fluide chirurgical situé dans la chambre de pompage, une ligne d'alimentation (217) pour alimenter le fluide chirurgical vers le réservoir, ladite ligne d'alimentation comportant un clapet anti-retour (153, 253),

des conducteurs et des connecteurs pour alimenter du courant vers lesdites électrodes, et au moins un orifice de décharge (604, 604", 704) fourni dans ladite extrémité distale dudit canal annulaire, et adapté pour que lorsque le fluide chirurgical est porté à ébullition dans la chambre de pompage, une impulsion de fluide chirurgical chauffé est déchargée d'une manière

re dirigée à partir dudit orifice de décharge.

2. Pièce à main (110) selon la revendication 1, dans lequel ledit réservoir de chambre de pompage (143) est défini sur des côtés opposés de celui-ci par une paire d'électrodes (145, 147) qui permettent à un courant électrique de circuler à travers les électrodes lorsqu'un fluide chirurgical est contenu dans le réservoir, de manière à porter à ébullition ledit fluide chirurgical et à propulser ledit fluide chirurgical vers le bas dudit canal annulaire. 5 10
3. Pièce à main selon la revendication 2, dans laquelle les électrodes sont isolées électriquement l'une de l'autre et du corps par une couche anodisée (159). 15
4. Pièce à main selon l'une quelconque des revendications 1 à 3, dans laquelle une pluralité d'orifices de décharge (604) sont agencés dans ladite extrémité distale, selon un motif divergent, un motif convergent, ou selon un motif non-convergent, presque sans motif. 20
5. Pièce à main selon l'une quelconque des revendications 1 à 4, comportant de plus au moins un orifice de décharge (606) agencé dans ladite extrémité distale dudit canal annulaire pour décharger un jet de fluide chirurgical chauffé (610) vers l'arrière dans ledit canal d'aspiration. 25 30

35

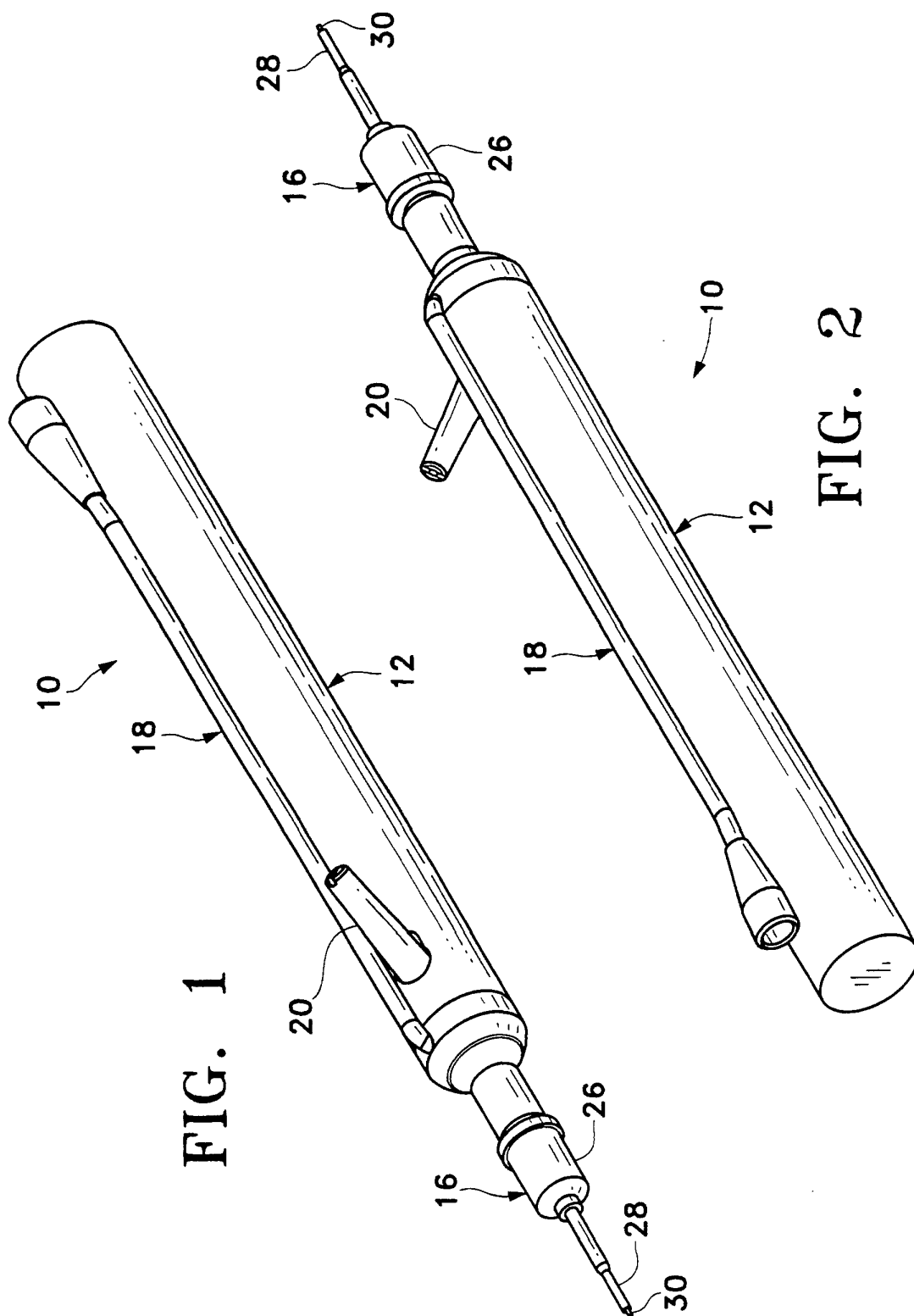
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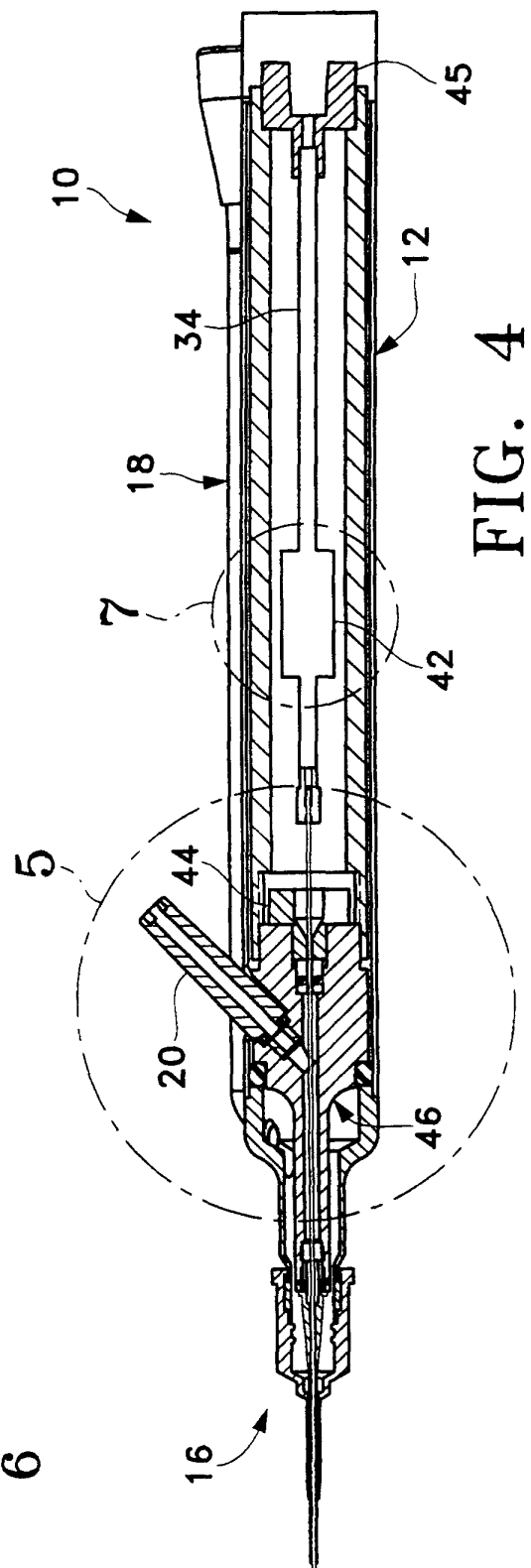
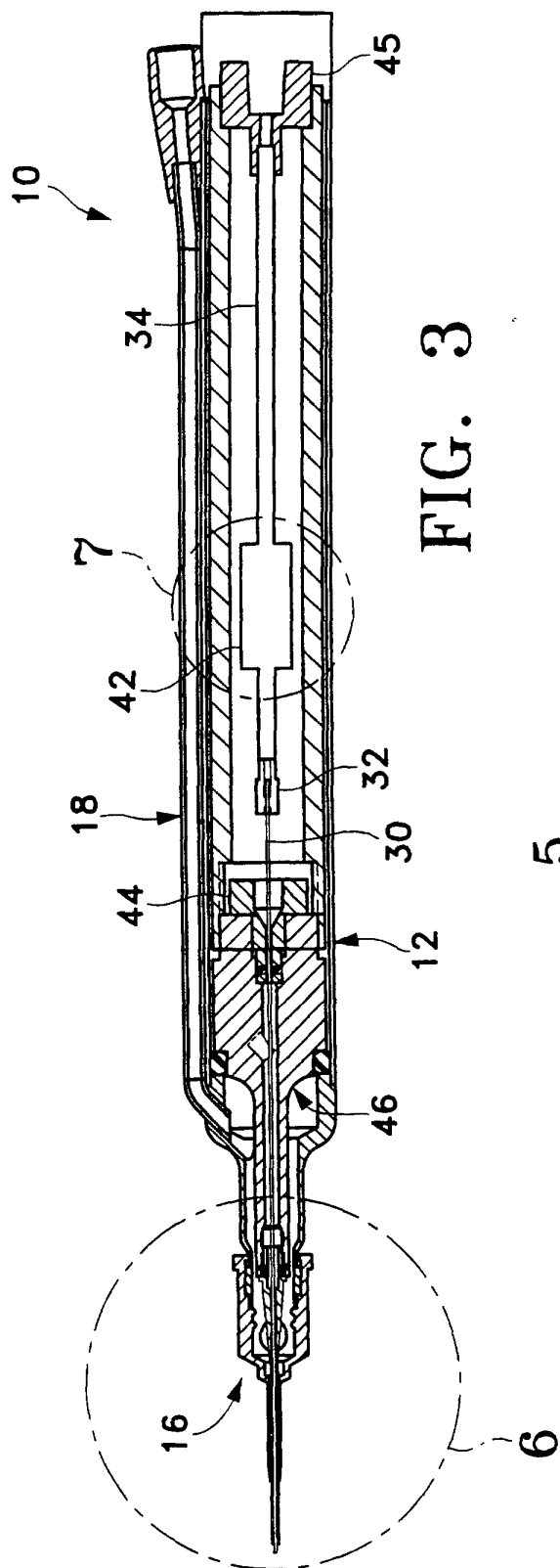
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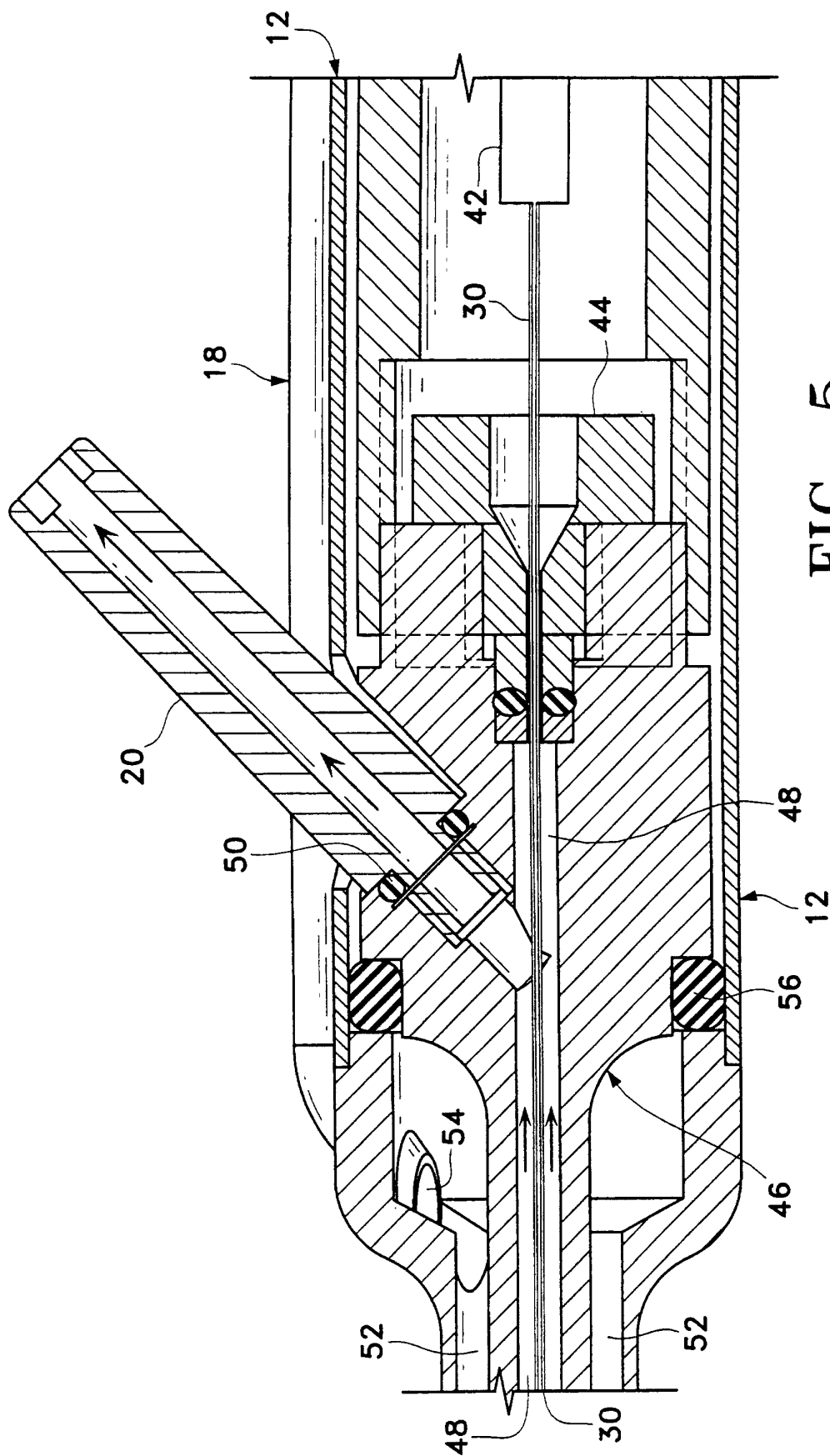


FIG. 5

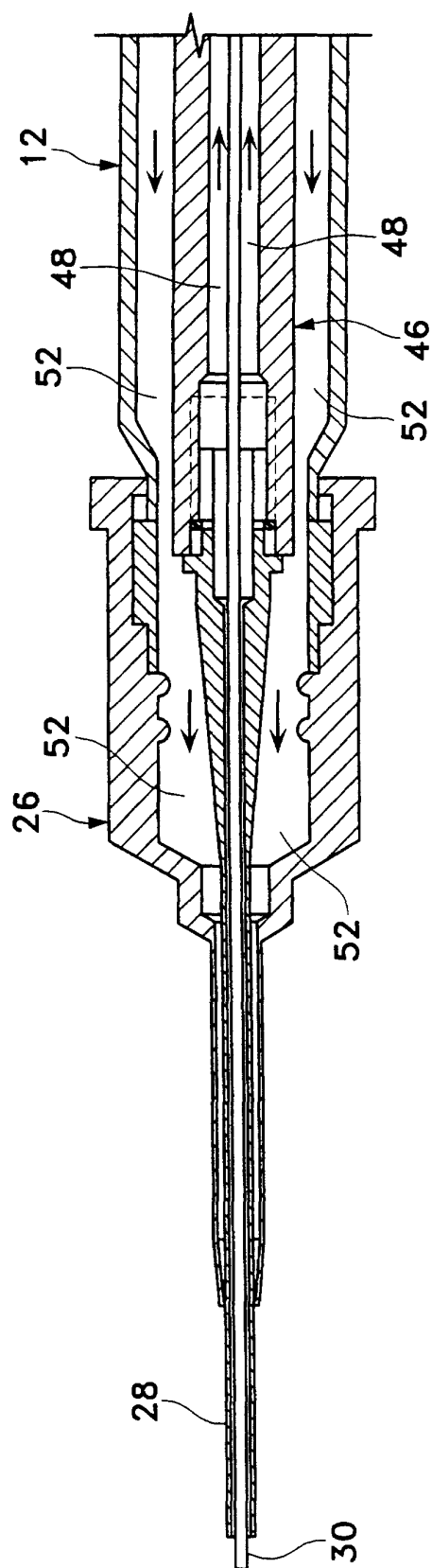


FIG. 6

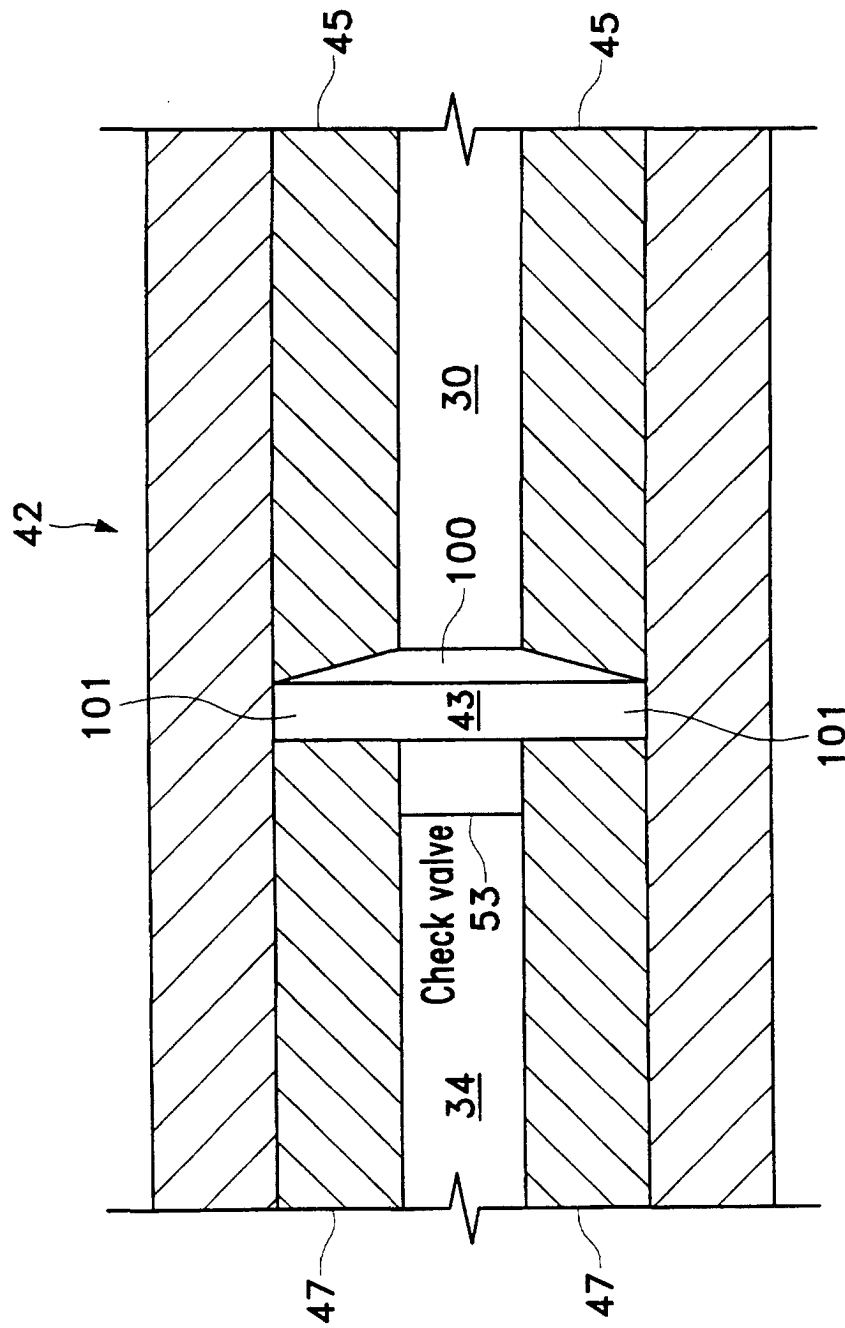


FIG. 7

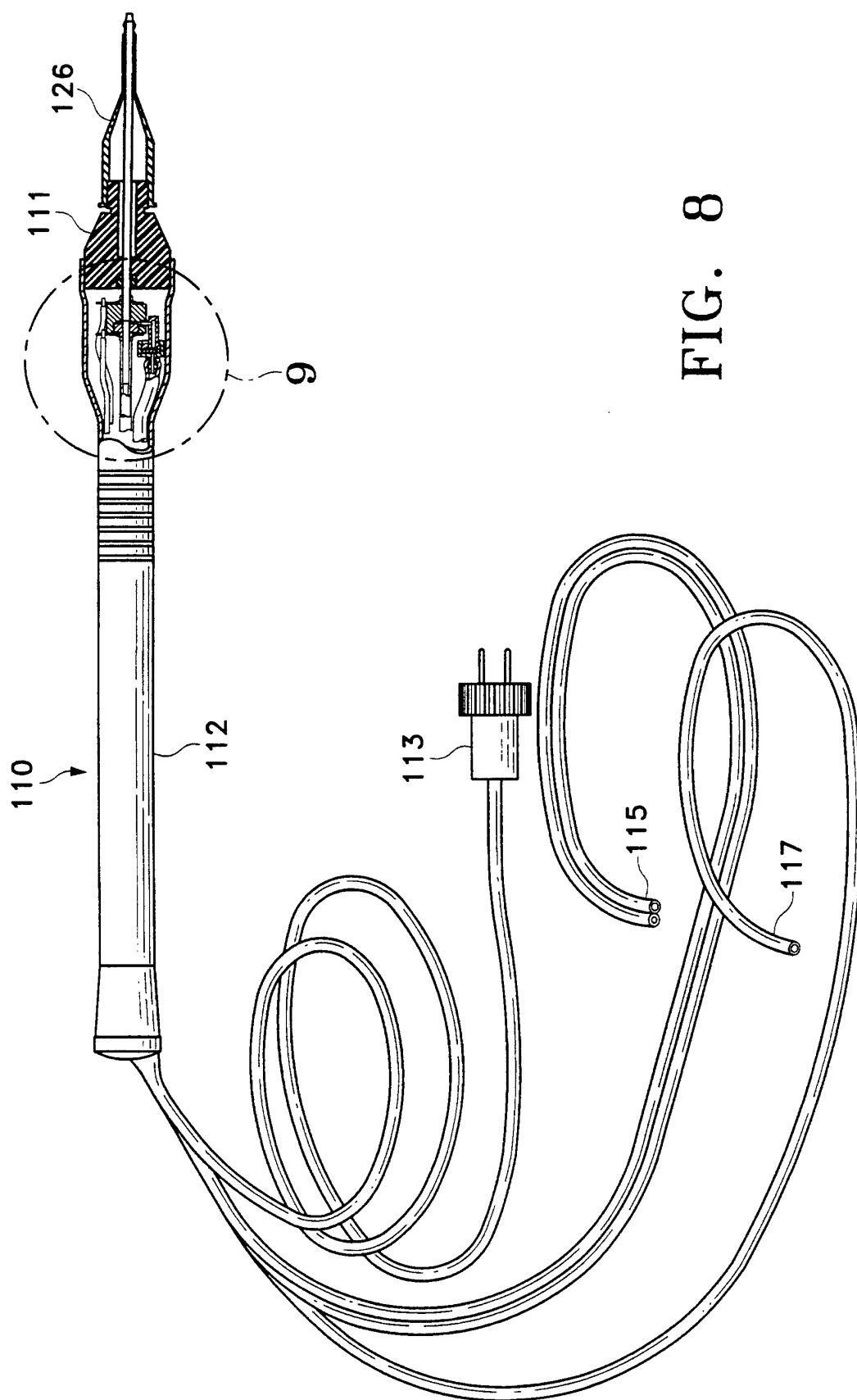


FIG. 8

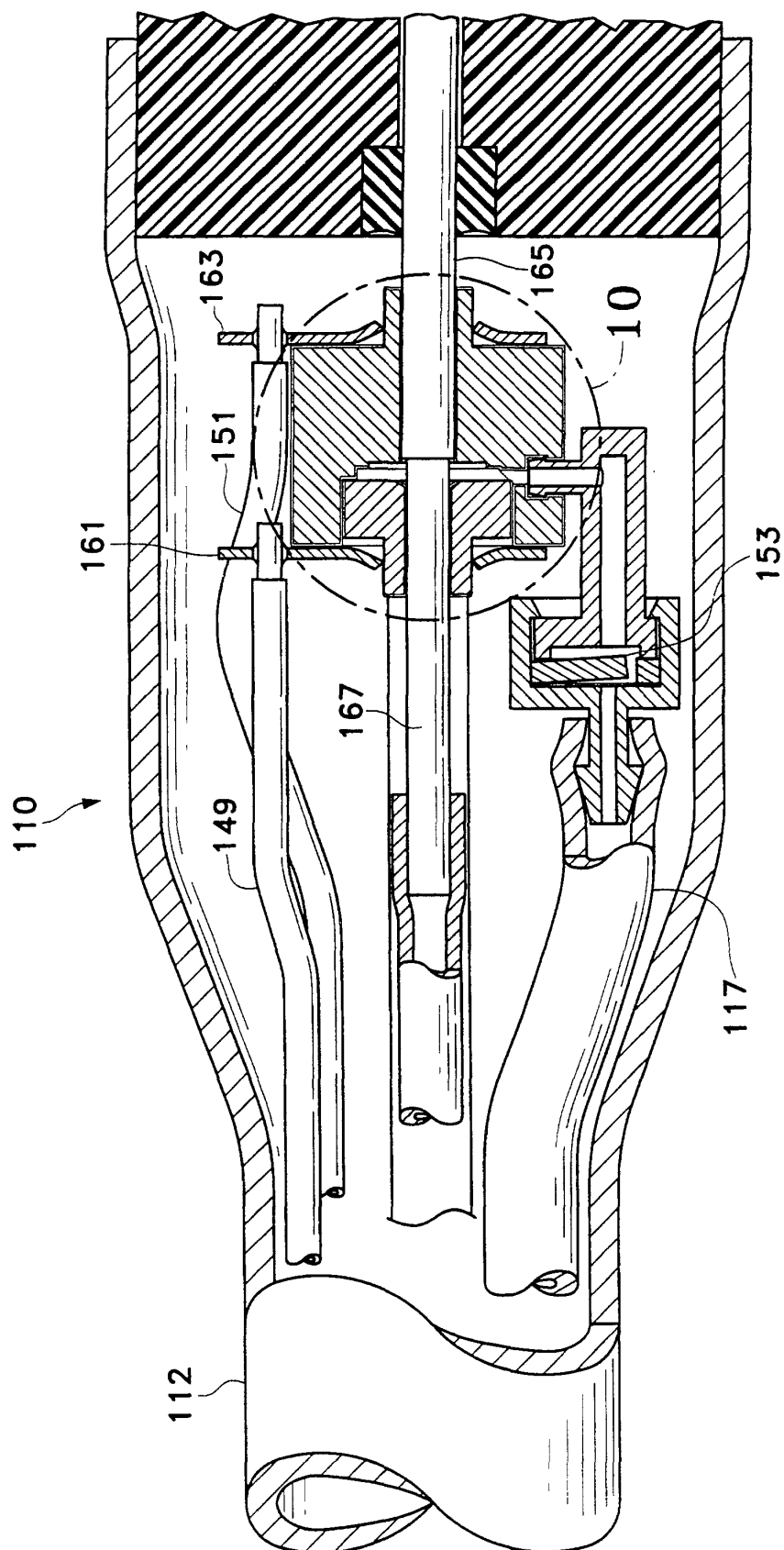


FIG. 9

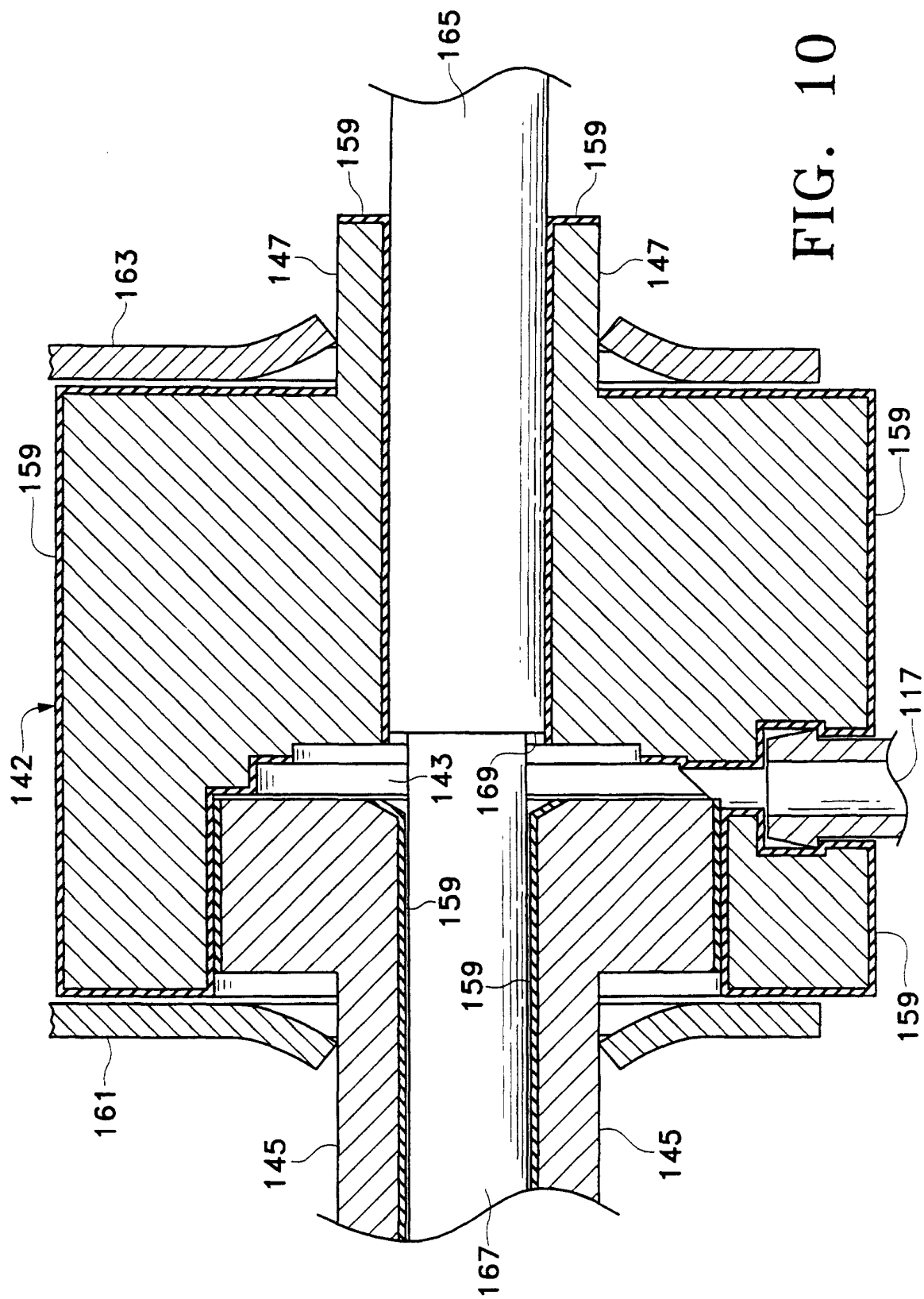


FIG. 10



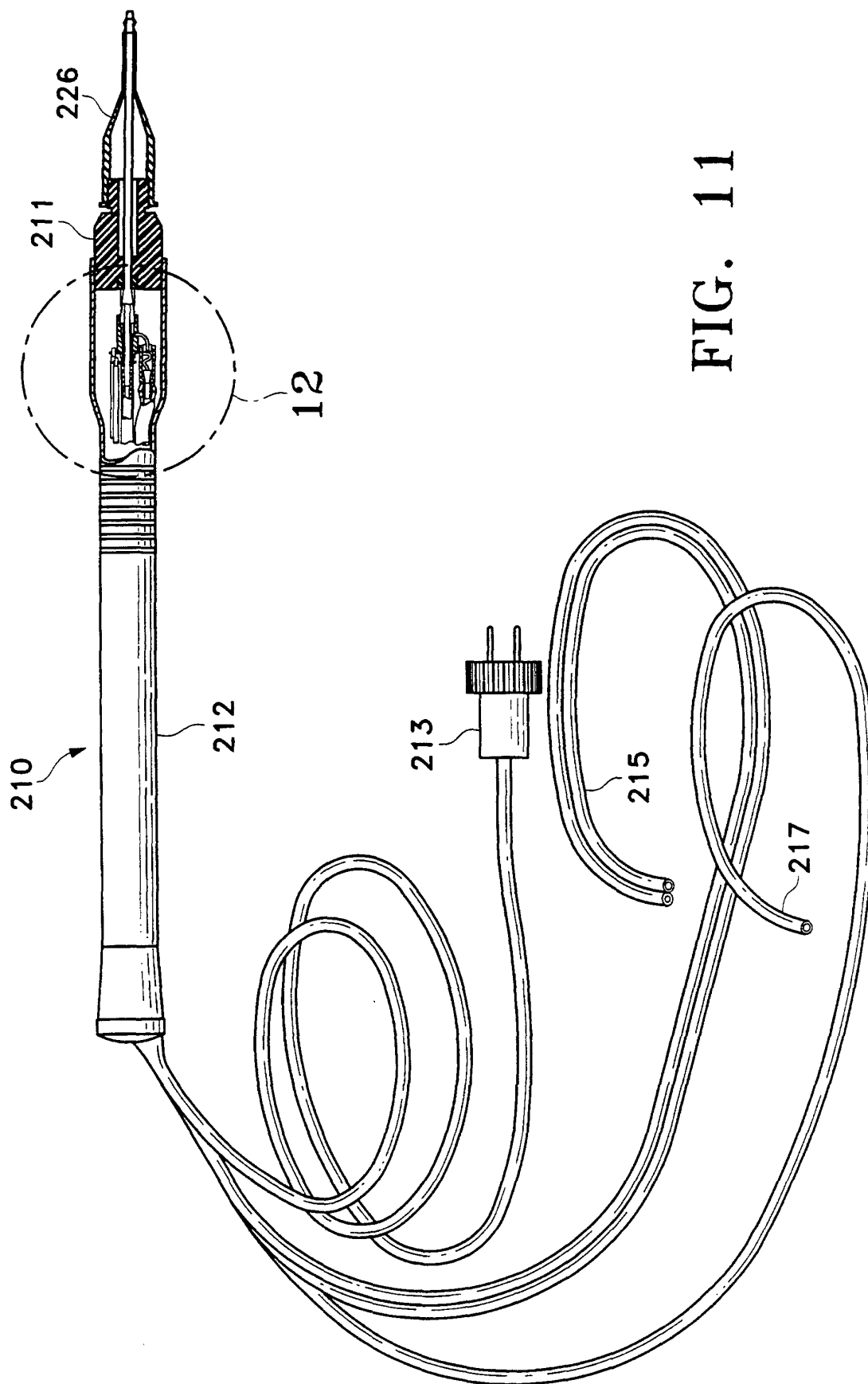


FIG. 11

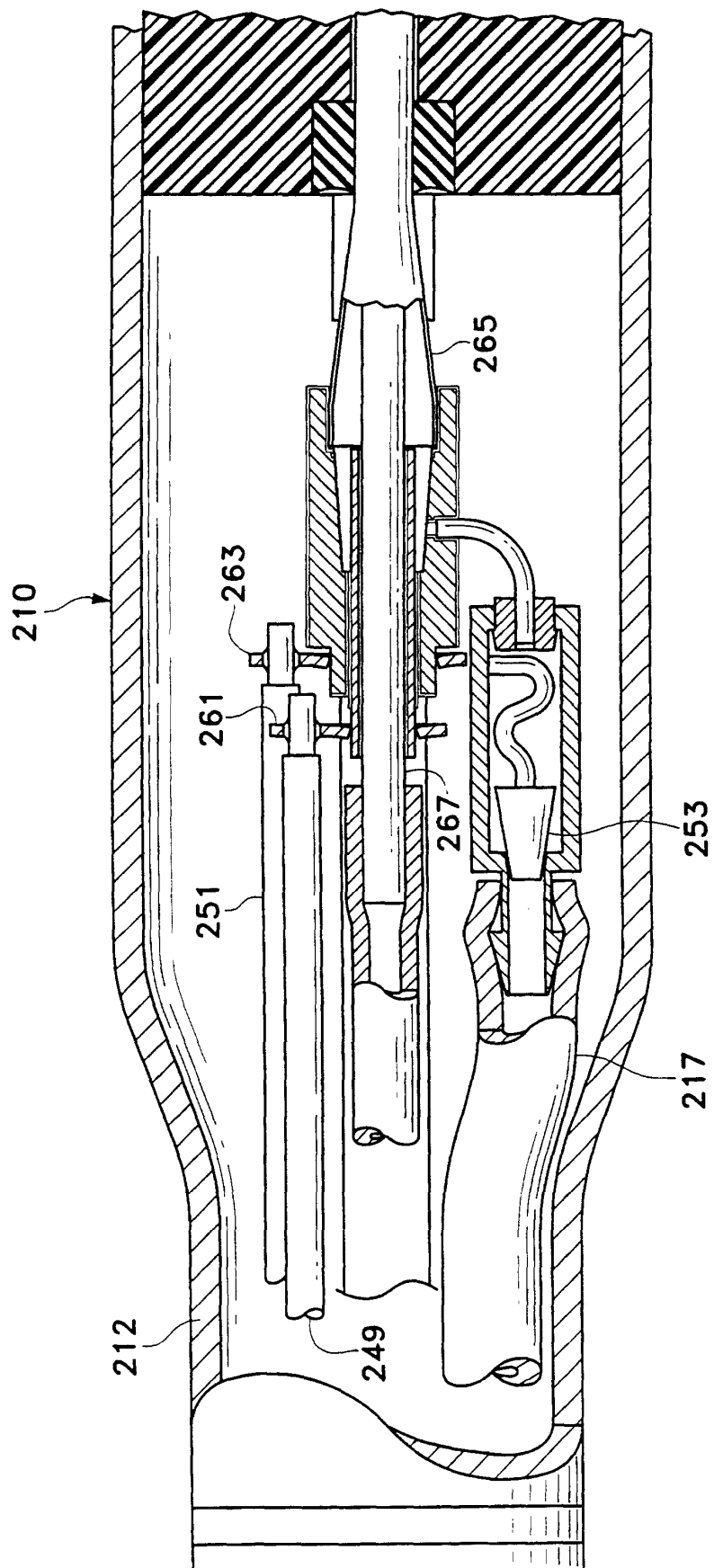


FIG. 12

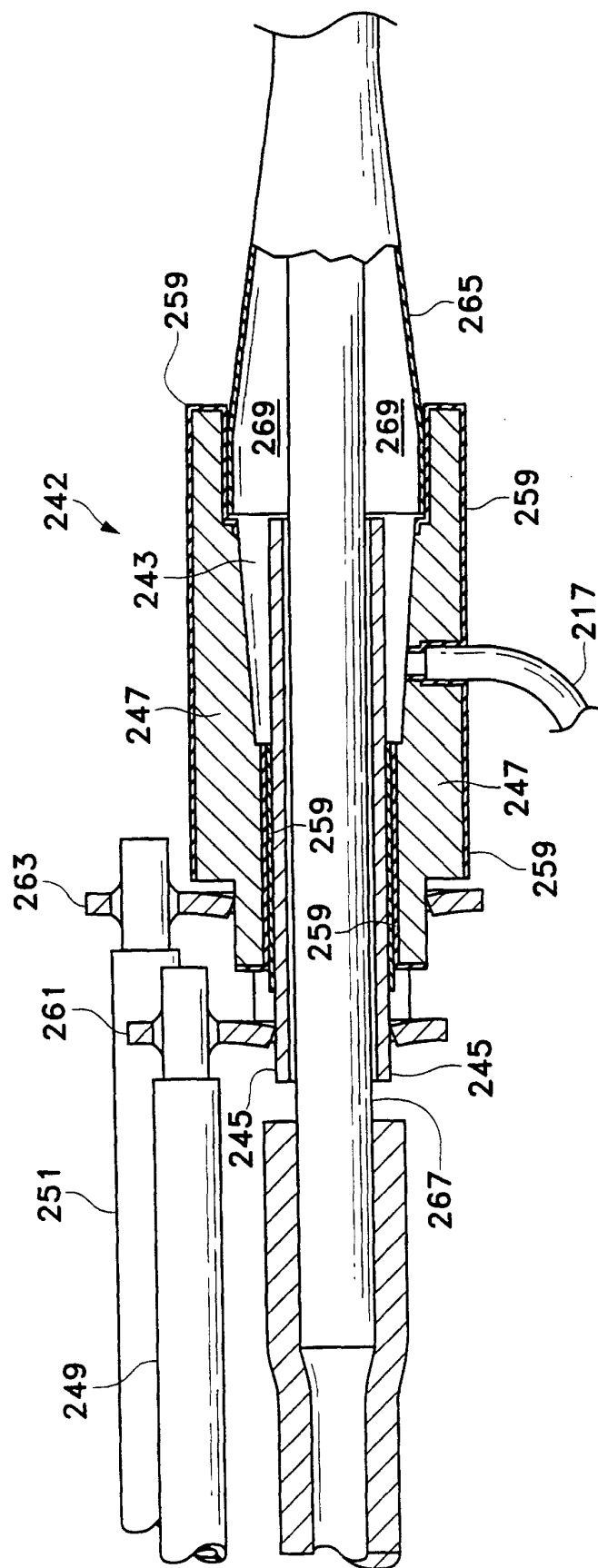


FIG. 13

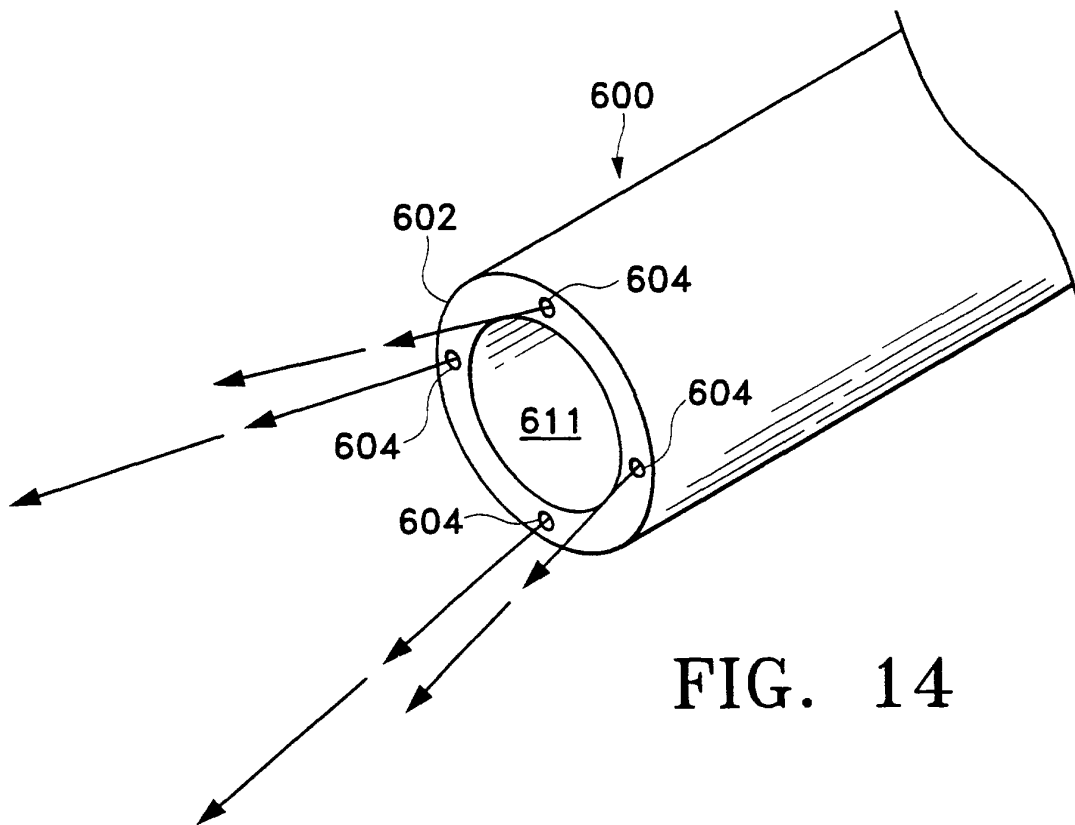


FIG. 14

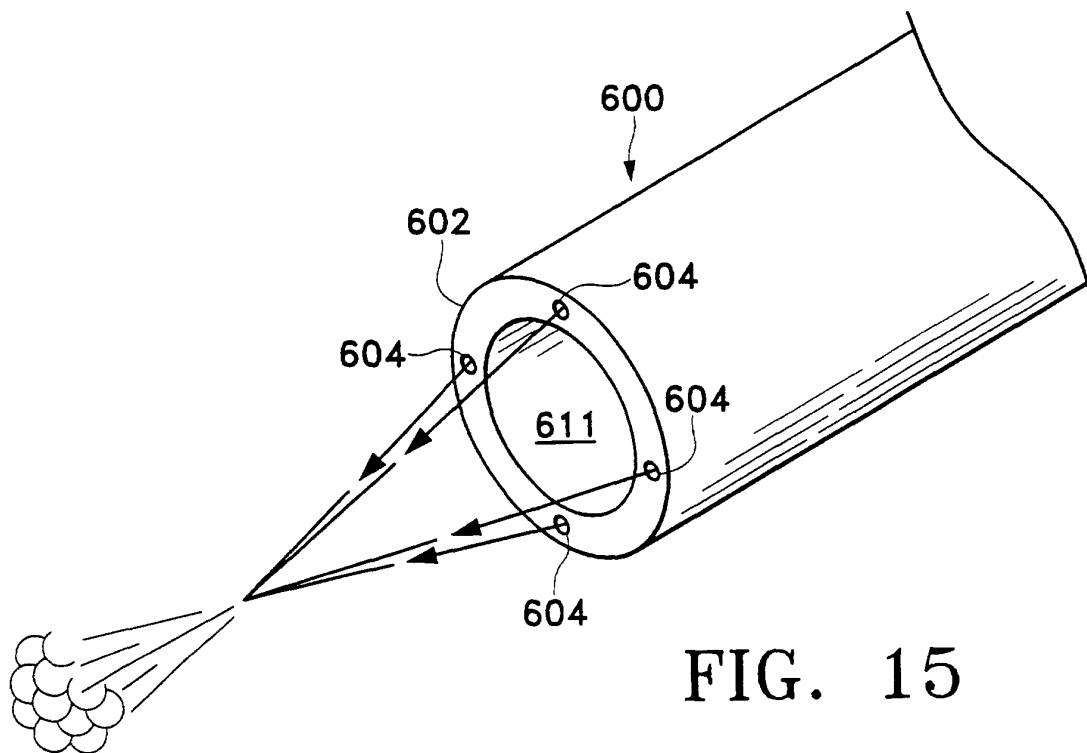
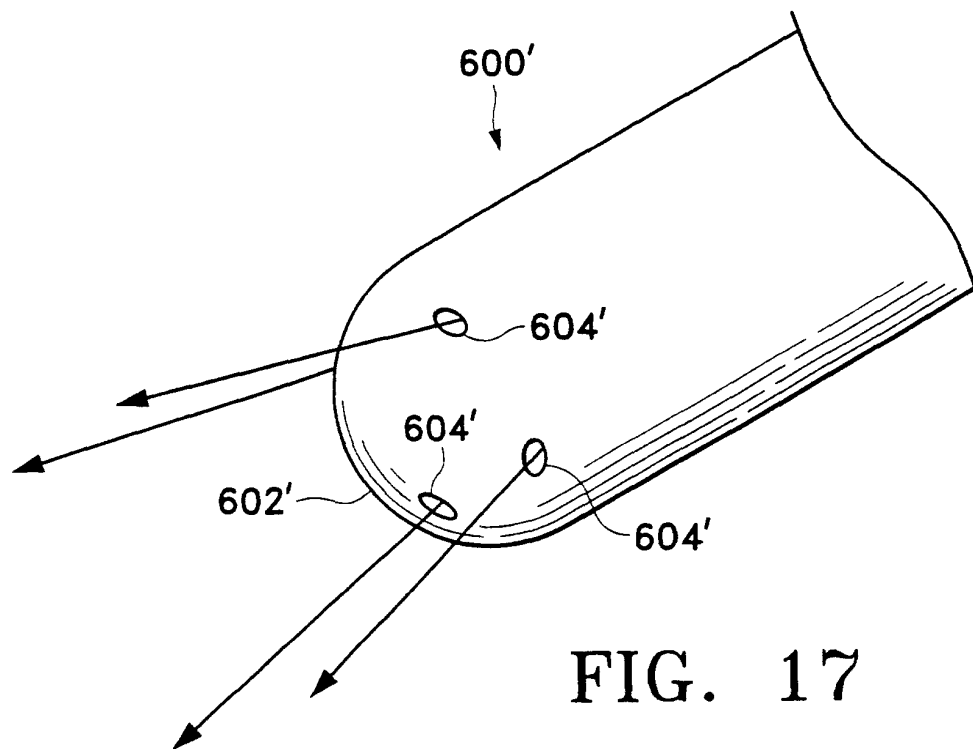
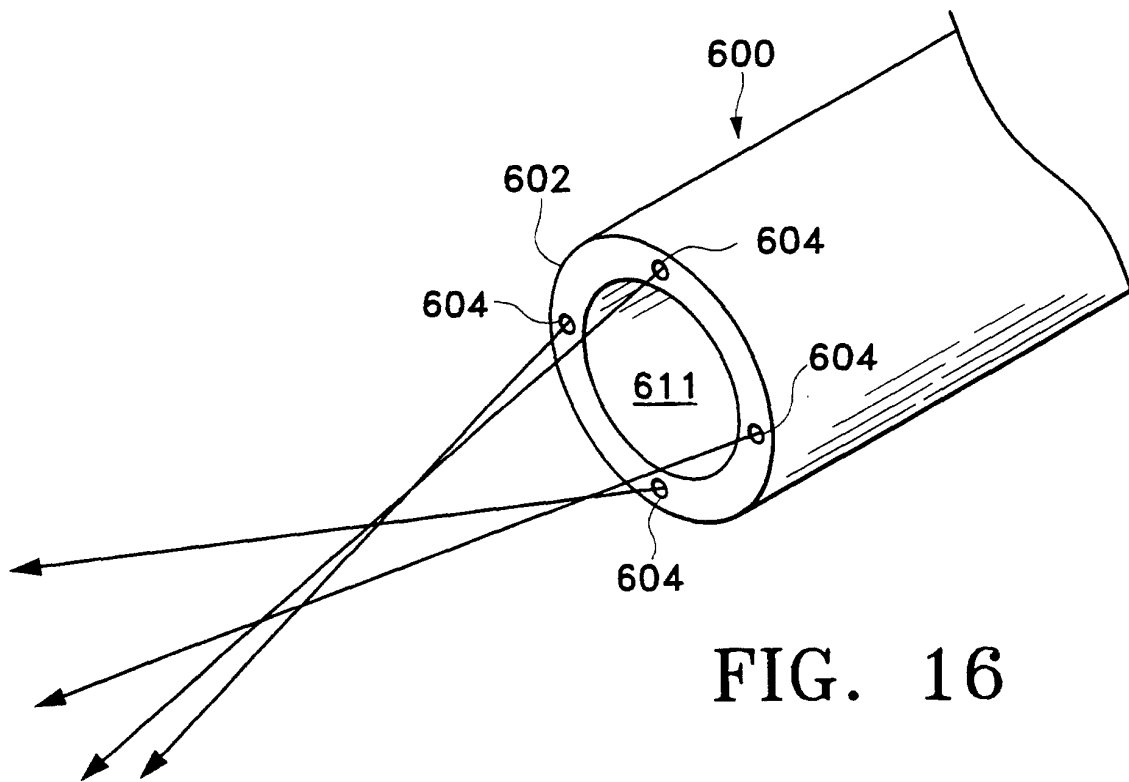
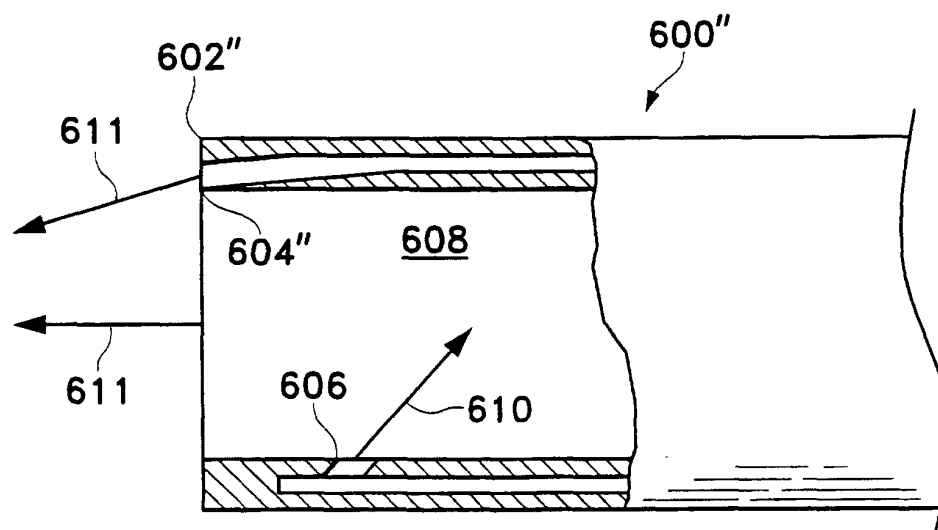
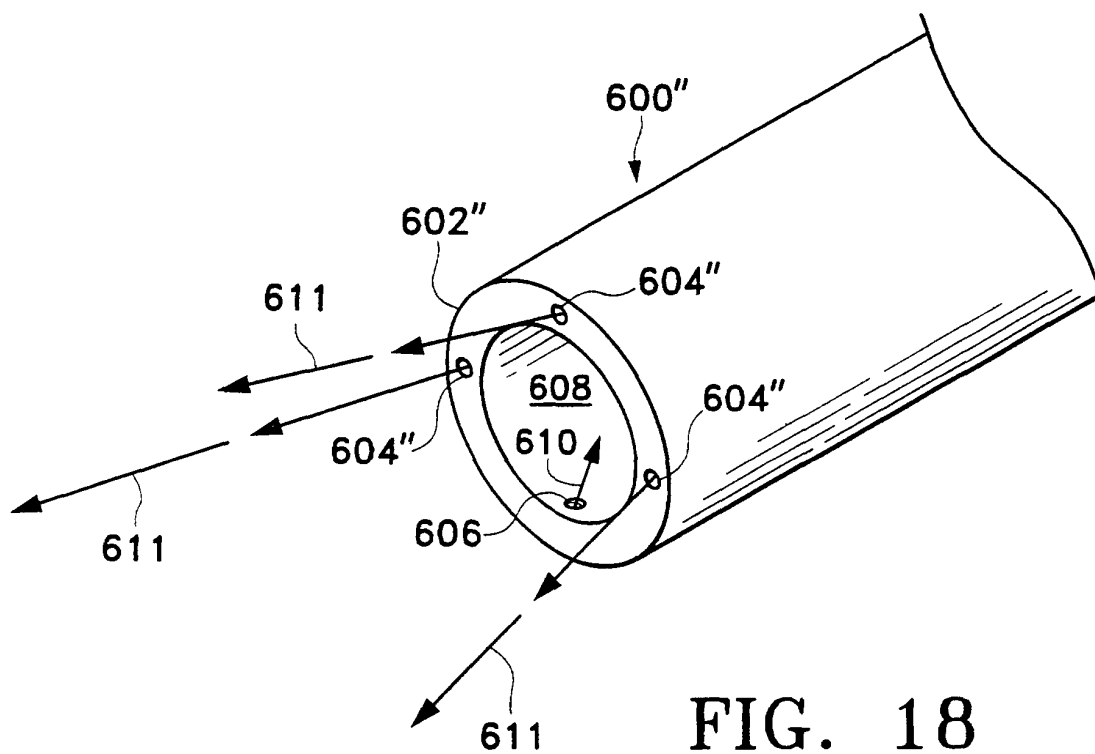


FIG. 15





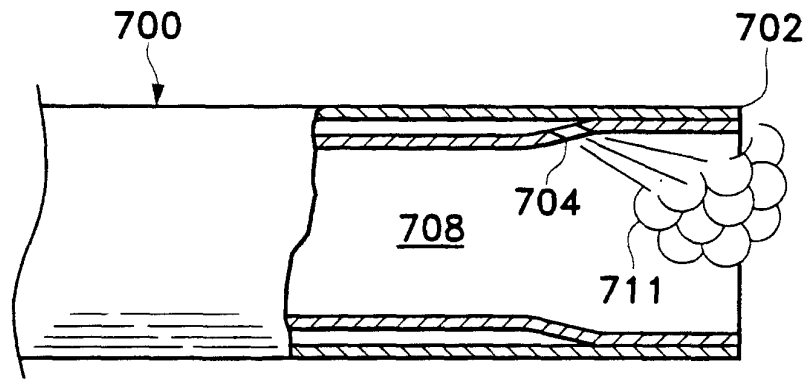


FIG. 20A

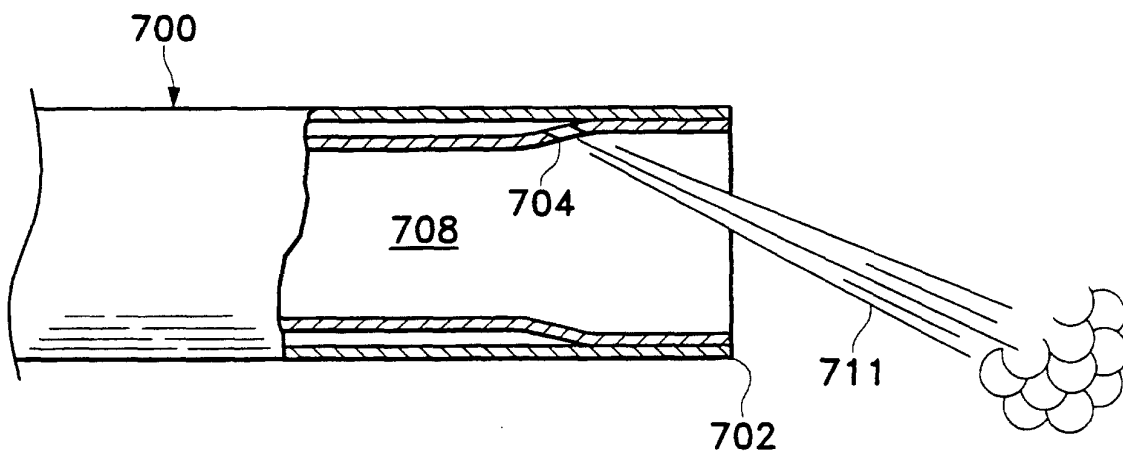


FIG. 20B

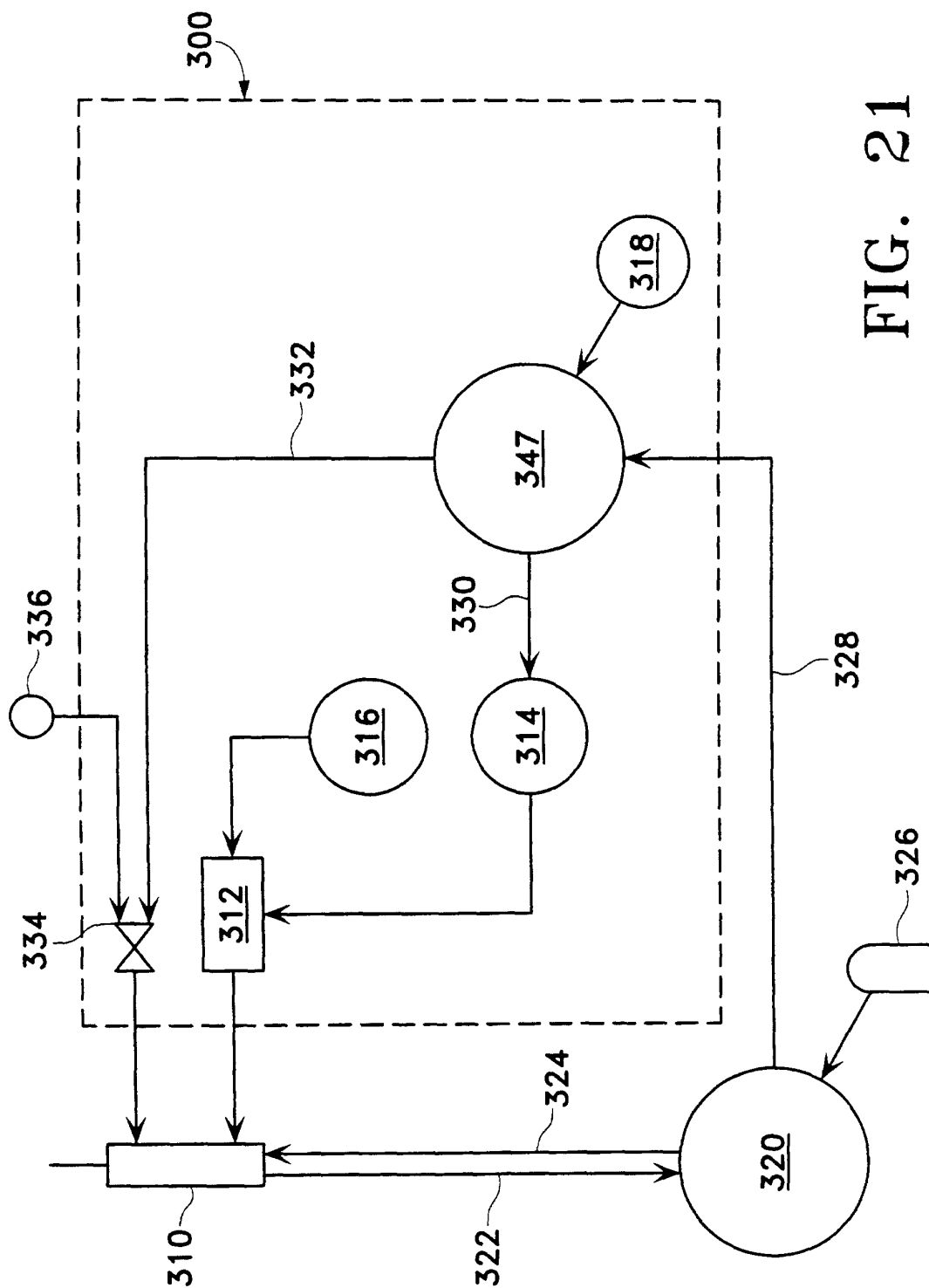


FIG. 21